WHY ARE ALCOHOL FUELS STILL ALTERNATE FUELS?

Reda M. Bata
Department of Mechanical and Aerospace Engineering
West Virginia University
Morgantown, WV 26506

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Abstract

The enthusiasm for using alcohols as alternate fuels in internal combustion engines (ICE) has been accelerating since the middle of 1970 and reached its peak by the middle of 1980. This was due to the serious effect of the exhaust emissions from automotive engines powered with oil-derived fuels coupled with a market rise in the cost of oil-derived fuels. Since then, the cost of oil has been decreasing and the need for alternate fuels has begun to slow down due to this economical reason. Alcohols are excellent fuels since they can be produced from renewable resources and their impact on health and the environment is limited. They are favorable for IC engines because of their high octane rating, burning velocities, and wider flammability limits. Experimental research and in-use applications showed drastic reduction in carbon monoxide (CO), particulate matter (PM), and moderate reduction in hydrocarbon (HC). Adverse effects on nitrogen (NO_x) and aldehyde (CHO) were also noticed.

Introduction

It is worth all of our efforts and dedications in order to become an energy-environment conscious nation. The attitude of increasing the stringent restrictions on pollutant emissions from automotive engines, the urgency for fuels derived from renewable sources, and the awareness of the expected rise in the price of oil-derived fuels in the future, have been the main motives of the 1990 Clean Air Act Amendments (CAAA) and the Energy Policy Act of 1992 (EPACT), Appendix A. Both acts are mandating the procurement of alternative fuel vehicles (AFV's) as well as imposing stringent exhaust gas emissions standards.

In the United States, the consumption of petroleum products exceeds the production rate of this strategic material. Meanwhile, the relaxation of the domestic companies to discover new oil fields because of the cheap surplus oil that is available in the international market, and the opposition from some environmentalists to explore new oil fields in the costal areas has been one of the major factors in creating the United States' negative balance of trade with other countries. Since new, revolutionary, non-traditional power plants are unexpected, and increasing demand is unavoidable as well, in the next few decades, the traditional IC engines will remain the prime power mover in our society. It took almost a century to develop the existing ICE, the oil refineries, and the distribution infrastructure. Huge investments have been dedicated for this business and they should be protected.

Alcohol fuels such as methanol (CH_3OH), ethanol (C_2H_5OH), iso-butanol (C_4H_9OH), methyl-tertiary-butyle-ether (MTBE), ethyle-tertiary-butyle-ether (ETBE), have proven to be excellent octane booster and blend with the traditional fuels, gasoline and diesel, and require minor engine modifications.

As stated in the National Energy Strategy in February, 1992, "The U.S. fleet of more than 185 million cars, buses, and trucks consume two-thirds of the oil used by the United States." In 1991, almost 50% of the oil consumed in our country was imported and it is expected that this percentage will increase up to 61% by the year 2010. The transportation system is consuming 63% of total U.S. oil consumption. The cost of damage to the environment caused by the exhaust gas emissions ranges from $11 billion to as high as $187 billion, (1). The aforementioned scary statistics have led the U.S. Department of Energy's (DOE) Office of Transportation Technologies (OTT), through its Office of Alternative Fuels, to support innovative-cost-effective methods to produce and implement alternative fuels and achieve greater penetration into the marketplace. Details of the production plan is explained in Appendix B. Among the alternate fuels are reformulated gasoline (RFG) additives such as ethers (oxygenated fuel additives), methanol, and ethanol. Higher alcohols, such as iso-butanol, were not mentioned because of their higher cost of production and lack of political support when compared to methanol and ethanol.

The Rationale for Alternate Fuels

Two main reasons justify the use of alternate fuels; the finite unrenewable supply of crude oil, and protection of the environment from the increasing ozone (photochemical smog) as well as the greenhouse effect. Since crude oil is cheap and available, demand for the use of alternate fuels will be realized in the long-term strategy. Protecting the environment is the short-term demand as was proven by the debate associated with the Clean Air Act Amendment in 1990. Use of alternate fuels in association with the new engine technology has the potential to reduce the harmful pollutants that cause damage to the environment.

Why Alcohol Fuels

There is no miraculous, super fuel that will satisfy all the requirements of cost effectiveness, maximum thermal efficiency, and engine performance, and still remain clean enough to protect the environment. Every fuel has advantages and disadvantages, and selection of a particular fuel is a function of different parameters including the physical properties of the fuel as shown in Table 1 (3). If we start with the disadvantages of the alcohol fuels, they might be summarized as follows:

1. The economics of production. Unless the cost of alcohol production from renewable resources is made cost-effective, there will be no demand for it. These alcohols could be produced from biomass, coal, and natural gas.
2. Flame visibility of alcohol is difficult to be detected, which might be hazardous. The lack of visibility is due to the small number of carbon atoms present in the alcohol. Since there is very little carbon, there is no soot formation to give the flame color.
3. Cold startability problems. Due to their low vapor pressure, high latent heat of vaporization, and single boiling point, alcohols, especially ethanol, have difficulty meeting industry standards for starting in cold weather.

The last two of these disadvantages, however, can easily be solved. By the addition of a small amount of gasoline to the alcohol mixture, a more visible flame will be produced and the effect of cold weather on engine startablity can be brought well within the industry standards.

Although there are a few minor disadvantages to the use of alcohol fuels, the advantages more than outweigh its easily solvable problems. The advantages are as follows:

1. Methanol can be made out of organic material such as biomass and municipal waste. In the long-term, it could even be made out of coal. The United States has 25% of the worlds' supply of coal, which will be abundant for years to come.
2. Alcohol combustion produces higher combustion pressures inside the combustion chamber of the ICE due to the higher molal products to reactants ratio, compared to gasoline, which improves power output and thermal efficiency (2).
3. Alcohols have a higher average octane rating $\{(RON+MON)/2=104\}$ compared to gasoline. Increasing the compression ratio of the engine to 12:1 or higher increases power and fuel efficiency by 20% and 15% respectivily (3&4).
4. Alchols have better combustion characteristics and performance due to the increased volumetric efficiency of alcohol fuels, which is why methanol is a preferred racing fuel. Acceleration time decreases with power increase.
5. In case of fire, alcohols have higher visibility for escape-rescue, low asphyxiation, produce cool flame and low heat output which causes low burns, low smoke damage,

residue is easily washed away, and are extinguishable with water and more readily by powders and foams.

6. In case of leaks and spillages, alcohols are miscible in water and could be washed out with water for quick and easy removal. They are easily metabolized if absorbed by the ground.
7. Alcohol fuels have a lower evaporative emission. Not as many harmful by-products will be released into the atmosphere by using alcohol fuels.
8. Since the carbon content in alcohol fuels is very small, a negligable amount of soot is formed and released to the atmosphere when burned in the ICE.
9. Alcohol fuels are liquids, which make them accessible using the same means of transportation and handling infrastrucure of the conventional fuels with minor modifications.

Alternate Fuels and Environment

Deterioration in air quality is a vital issue that needs to be seriously monitored and limited. The transportation system is a major air pollution contributor due to the exhaust emissions such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), carbon dioxide (CO_2), and particulate matter (PM). The transportation system is estimated, by the U. S. Enivironmental Protection Agency (EPA), to produce up to 44% of the total hydrocarbons emissions inventory in the U.S. The evaporative emissions share 31%, and the balance of 13% is from exhaust gas emissions. Production rate of exhaust gases differ from one place to another based on different parameters such as the geographic locations, altitude, weather conditions, traffic congestion, population, maintenance availability, etc. The greenhouse effect, which is caused by the production of carbon dioxide, has been suspected to cause the global warming and its adverse effect on the biological system. Ozone production is due to the chemical reaction between nitrogen oxides, hydrocarbons, and sunlight, which is known as photochemical smog. Los Angeles' polluted environment with photochemical smog is a good example, and is considered as one of the most non-attainment areas in the nation.

Implimentation of alternate fuels, in many pilot project over the nation, with dedicated and converted IC engines, has a positive effect on carbon monoxide and particulate matter reduction. Hydrocarbons emission, which is mainly "evaporative emission" is reduce when alcohol fuels are used. This trend is obvious in Table 2, which shows in-use emission measurements of regulated pollutants from jet A and neat methanol fuels, for similar vehicles and similar engines under transient test conditions. Hydrocarbons data do count the evaporative emissions which make up approximately 65% of the hydrocarbons emissions. In another study of carbon monoxide under steady-state conditions, wide open throttle (WOT), no load (NL), intermidiate load (IL), and full load (FL) are shown in Table 3. Four different fuels-20% by volume iso-butanol -gasoline blend (B20), 20% ethanol-gasoline blend (E20), ethanol-gasoline blend (20M), and base line gasoline (GAS)-were used. Carbon monoxide emissions from alcohol-gasoline blends were lower than that from gasoline, and M20 was the lowest.

Conclusions

Why are alcohol fuels still alternate fuels? Apparently, since production and use cost of conventional fuels (gasoline and diesel) are very cost-effective, nobody will use alcohol fuels except the Federal and State Governments because of the CAAA and EPACT through the AFV's programs. What about special fleets of companies, private sectors, and individuals ? We are not yet environment-concious users !

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Appendix A

Clean Air Act Amendments of 1990 (CAAA) -- The CAAA requires fleets in 22 urban regions to begin operating clean fuel vehicles (CFV's) by the end of the decade.. Beginning in 1998, 30 percent of new vehicle purchases by many fleets must be CFV's. This increases to 50 percent by 1999 and 70 percent by 2001. Stringent future emission standards are also established for cars, light-suty and heavy-duty trucks, and buses.

Energy Policy Act of 1992 (EPACT) -- EPACT establishes requirements for the purchase of AFV's in both public and private fleets. These requirements begin in 1993 for frderal fleets, 1996 for state and fuel supplier flets,and if necessary, in 1999 for private and municipal fleets. EPACT also provides economic and other incentives for fuel suppliers, original equipment manufactureres, and fleet owners.

Appendix B

Production of alcohol fuels on developing cost-effective biomass-to-fuel processes. The following strategy has been adopted by the DOE.

1. Establishing cost-effective techniques for growing the biomass resource.
2. Developing high-yield, low cost systems for converting biomass to fuels.
3. Demonstrating alternative fuels(including methanol, ethanol, and natural gas) in vehicle fleets across the United States.
4. Acquiring data on the performance of alternative-fueled vehicles from fleets across the U.S.

Selection and production of energy crops that have high-yield biomass feedstocks is a primary step in the biomass-to-fuel process. Energy crops that can be grown in short-rotation such as trees (2-8 years), grasses that can thrive in marginal conditions, and aquatic plants such as algae with high oil (lipid) content. Researchers and scientists are genetically manipulating trees and grasses to increase yield which would produce more alcohol in less time.

Table 1: Properties of Fuels

Characteristic	Gasoline	NO.1 Diesel fuel	Methanol	Ethanol	Iso-butanol	Gasohol
Chemistry	Mixture of Hydrocarbons	Mixture of Hydrocarbons				90% Unleaded Gasoline 10% Ethanol
Specific Gravity @ 60 F	0.72 - 0.75 *	0.82	0.79	0.79	0.81	0.73 - 0.76
Boiling Point o F o C	 85 - 437 30 - 225	 360 - 530 190 - 280	 149 65	 173 78.3	 227 108.1	 77 - 410 25 - 210
Net Heating Value (Mass) BTU/lb MJ/kg	 18,700 43.5	 18,500 43	 8,600 20.1	 11,600 27	 14,000 33	 18,000 41.9
Net Heating Value (Volume) BTU/gal MJ/l	 117,000 32	 126,000 35.3	 57,000 15.9	 76,000 21.3	 93,000 26	 112,900 30.9
Heat of Vaporization BTU/lb kJ/kg	 170 400	 250 600	 500 1,110	 390 900	 250 578.4	 200 465
Vapor Pressure @ 100 F psi kpa	 9 - 13 62 - 90	 0.05 0.34	 4.6 32	 2.5 17	 0.33 2.3	 8 - 16 55 - 110
Octane Number Research Motor	 91 - 100 82 - 92	Not applicable	 112 91	 111 92	 113 94	Note 1
Cetane Number	Below 15	40 - 60	Below 15	Below 15	Below 15	Not applicable
Stoich. Air/Fuel Ratio	14.6	14.6	6.4	9	11.1	14
Vapor Flammability Limits	0.6 - 8	0.6 - 6.5	5.5 - 26	3.5 - 15	Note 2	Note 3
Appearance	Colorless to light amber color	Colorless to light amber color	Colorless	Colorless	Colorless, viscous	Colorless to light amber color
Vapor Toxicity	Moderate irritant	Moderate irritant	Toxic even in small doses	Toxic in only large doses	Moderate irritant	Moderate irritant

* For premium gasoline the range is 0.73 - 0.78 (0.75 is used in this study)

Note 1: May be the same as gasoline, or add 1.5 or 2 numbers depending on blending practice

Note 2: Values not available

Note 3: Values not published

Sources: SAE 820261, SAE 890434, Bosch Automotive Handbook

Table 2. Exhaust Gas Emissions For Jet A and Methanol 100

Vehicle	Fuel	CO	NOx	HC	PM
1	Jet A	37.8	32.3	2.41	0.72
2	M100	22.2	86.5	5.77	0.22
3	M100	18	19.5	6.95	0.1
4	M100	25	20.8	7.5	0.17

Table 3. Carbon Monoxide Emissions
from Different Fuels

Fuels	1250 RPM (NL)	2200 RPM (IL)	2500 RPM (FL)
Gas	4.21	0.135	2.51
B 20	2.4	0.13	1.38
E 20	1.5	0.125	0.69
M 20	1.45	0.124	0.61